THE ROLE OF CLEAN COAL TECHNOLOGIES IN A DEREGULATED RURAL UTILITY MARKET

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ABSTRACT

The nation's rural electric cooperatives own a high proportion of coal-fired generation, in excess of 80 percent of their generating capacity. As the electric utility industry moves toward a competitive electricity market, the generation mix for electric cooperatives is expected to change. Distributed generation will likely serve more customer loads than is now the case, and that will lead to an increase in gas-fired generation capacity. But, clean low-cost central station coal-fired capacity is expected to continue to be the primary source of power for growing rural electric cooperatives. Gasification combined cycle could be the lowest cost coal based generation option in this new competitive market if both capital cost and electricity production costs can be further reduced. This paper presents anticipated utility business scenarios for the deregulated future and identifies combined cycle power plant configurations that might prove most competitive.

I. NRECA and RER

NRECA is the national trade association representing the nation's nearly 1000 consumer-owned electric cooperatives. Recognizing the importance of science and technology to the success of its electric cooperative members, NRECA administers a research and development program for its member systems known as the NRECA Rural Electric Research (RER) Program. RER is voluntarily funded by participating member cooperatives at approximately $4.5 million annually. RER works closely with EPRI and other utilities to ensure that industry-wide technology developments may be applied to the unique needs of rural electric systems in a cost-effective manner.

II. UNIQUENESS OF ELECTRIC CO-OPS

Electric cooperatives, for the most part, serve sparsely populated rural and agricultural areas of the U.S., representing some of the nation's least developed and roughest terrain. Even so, co-ops sell about 7.5% of the nation's power to 30 million consumers in 46 states, and own nearly half of the distribution line miles in the country in order to deliver this power to their consumers. Co-ops average about five

consumers per mile of line compared to the rest of the electric utility industry's average of around 40 customers per mile. Since electric revenue is a direct function of customer density, providing economical electric services to rural consumers is a challenge. This is complicated by the fact that much of rural electric load growth occurs at the end of long feeders. Thus, expensive transmission and distribution right-of-ways must be acquired in order to upgrade or provide new lines for increased power supply to these locations via conventional central station service.

III. CO-OP POWER SUPPLY TODAY

Currently, nearly one-half of electric cooperative power needs are provided by 60 generation & transmission (G&T) cooperatives. These G&T cooperatives are owned by the distribution cooperatives they serve. From an operational point of view, rural electric generation facilities are not very different from the rest of the utility industry. Where co-ops are different is that they own a high proportion of coal-fired generation, in excess of 80 percent of their generating plant capacity. Co-op generating facilities are environmentally the cleanest in the industry because they are the newest. Forty-four percent of the co-op coal-fired capacity already has flue gas scrubbers compared to 20 percent nationwide. All together, co-ops own or have ownership in 11 of the nation's lowest-cost power producers.

IV. DEREGULATION

NRECA and its member systems have actively participated in the policy deliberations involving deregulation of the nation's electric utility industry. Chief among the possible changes anticipated is the "unbundling" of the services performed by what has historically been a vertically integrated industry. Unbundling proposals could separate the electric utility industry into four distinct components: generation, transmission, distribution and energy services.

Generation Company (GENCO)

The generation part of the business will in all likelyhood compete in an open wholesale market. Restructuring advocates often propose that the generation component of an electric utility's business be sold to an independent company or spun off to a separate unregulated utility affiliate, a GENCO. The power would be sold at whatever price the seller could obtain in the generation market at a given time—known as a *market-based* rate. This means that power rates would not be *cost-based* on what it took to produce the power, but rather only the price the power could command in the marketplace.

Transmission Company (TRANSCO)

Transmission, following the finalization of Federal Energy Regulatory Commission (FERC), Orders Nos. 888 and 889, will be an open access system. Restructuring proposals often call for the transmission

component of an electric utility's business to be given to a separate regulated TRANSCO, or even handed off to an "Independent System Operator" (ISO). Most proposals would continue regulation of transmission, on the assumption that it is unlikely for substantial competition to develop in the transmission sector. This is due to the difficulties and high costs of building transmission lines, getting rights of way and obtaining needed environmental and land-use clearances. Since bulk transmission lines often transmit power that comes from other states, plans call for FERC to regulate the price for and terms of transmission services.

Distribution Company (DISCO)

Under many restructuring proposals, the distribution component would be handed by a separate regulated distribution company, called a DISCO. Like transmission, most proposals would continue the regulation of DISCOs, because of the high cost of building duplicate distribution lines, and the aesthetic/environmental constraints. Virtually, all plans call for state regulation of DISCOs.

However, DISCOs would not necessarily perform all of the functions that we currently think of when we think of electric distribution companies. Many proposed DISCOs would carry out a pure *wires* (electricity delivery) function. The actual sale of electricity at retail is generally proposed to be open to competition. Retail customers would pick their electric power supplier just like they now pick their long-distance telephone service provider. This separation of the *wires* functions from the actual sale of the power is the essence of *retail wheeling, retail access,* and *customer choice,* terms we have all heard as part of the restructuring debate. Retail access is at the heart of the restructuring debate. Restructuring advocates want retail customers to be able to purchase their electric power from any one of a number of suppliers, with the power being transmitted and delivered by an entity distinct from the supplier. For the utility that owns the DISCO to compete for actual electricity sales to retail customers, it would have to form its own separate marketing entity, and that entity would have to use the DISCO for delivery service, just like any other supplier.

Energy Service Company (ESCO)

Retail electric distribution service may be split up into a number of parts: *delivery, retail sales,* and *energy services.* Retail sales could be made by generators, marketers, brokers, aggregators of all sorts. The providers and types of energy services are just beginning to emerge. Some envision separate energy service companies (ESCOs) that would become the marketers of a wide-range of services such as purchasing electricity from power producers, repackaging the electricity with valued-added consumer services and seeking out markets in which compete.

V. IMPACT OF DEREGULATION

These potential changes will have a substantial impact on every aspect of the electric utility business. A broadly-based task force drawn from NRECA's membership studied the likely industry changes and

recently issued an initial report on the resulting competitive issues. The task force arrived at five conclusions that will receive a great deal of attention from electric cooperatives and may have implications for the entire industry. These are felt to be valid regardless of how the industry finally restructures:

- Customers will have their choice of an energy provider;
- There will be increasing pressure to regulate all distribution operations;
- The future of all power supply arrangements is unclear;
- The advantage of electric co-ops is their strong relationship with consumers;
- Future success requires being competitive on price, service and reliability.

Even though the final industry restructuring is not yet known in detail, one can draw certain general conclusions about the four proposed utility functions that may evolve:

Transmission

This part of the business will be regulated as an open access network by the federal government through FERC. The past decade has seen a four-fold increase in bulk power transfers across the country. Now, 40% of the electricity generated in the U.S. is sold by the producing utility on the bulk power market before it reaches consumers. Such wholesale transactions, which involve electricity transfers over transmission networks, are expected to increase significantly because of federal deregulation producing open access to the networks. Transmission systems, for example, now experience loads at 70% or more of their capacity less than 20% of the time. For distribution systems, the corresponding capacity utilization occurs less than 5% of the time. Thus, there appears to be adequate capacity to handle the increased transactions that might result from deregulation. But technology is expected to be able to accomodate substantially greater power transfer capability over existing systems if needed.

Distribution

This part of the business will likely be regulated by the states. There is a consensus that it does not make sense for multiple wires and service entrances to be installed depending upon who you elect to provide your power. As a result, regulations will be necessary to compensate the one *wires* company delivering power, while preventing monopolistic pricing policies that would be unfair to the customer. While state-level deregulation will give consumers greater choice among electricity providers, at the same time, consumers are increasingly concerned about the power quality. Momentary disturbances that would have gone unnoticed in the past will become a major concern in the future, causing computers and other digital equipment to malfunction (i.e., the “blinking clock syndrome”). As a result, successful DISCOs will be those that deliver high-quality power at low cost and follow it up with excellent customer service.

Energy Services

ESCOs would likely be unregulated entities competing in the marketplace to provide power to customers. ESCOs would be able to buy bulk power and resell it to consumers along with additional services, or provide distributed generation at or near a customer site. In either case, economics will dictate the choice of generation selected by the ESCO for a particular application. Some predict distributed generation to be as much as 30% of new electric generation by 2010. If true, that would be more than 50 gigawatts of the 175 gigawatts of generation growth that the U.S. Energy Information Administration (EIA) expects by then. NRECA believes distributed generation will be a valuable power supply option for servicing many rural customer loads. But, the electric co-ops see a much more modest growth in distributed generation by 2010, probably not exceeding 5 to 10 percent of total generation expansion, if that much.

Generation

Although FERC and others are still working out the details, it appears likely that the generation part of the business may ultimately become totally deregulated and truly compete on the open market to sell the electricity it produces. This power will be sold as a commodity like oil or corn. In fact, electricity futures markets are already being formed in anticipation of the public buying and selling bulk electricity transactions just as is the case with other commodities.

In such a marketplace, only the low-cost providers survive. Unlike ESCOs that will provide distributed generation at a premium cost level of perhaps 4 to 5 cents/kWh or more along with services to solve a customer problem, GENCOs will sell bulk power strictly on the basis of what the market will pay for this commodity. Average power production costs in the U.S. dropped below 2 cents/kwh for the first time since 1981 according to the Utility Data Institute. So it is reasonable to assume that the production cost threshold could be around 2 cents/kWh or less in order to successfully compete with bulk power sales in the new electricity marketplace. Thus, decisions to build new central station power plants in the future will be based on three criteria:

- Cost of electricity;
- Short construction lead time;
- Flexibility of the technology to achieve performance and cost goals in plant sizes ranging from 100 mW to over 1000 mW;
- The ability of the technology to meet ever-tightening environmental requirements without significant additional capital costs.

NRECA sees a continuing important role for coal in the new generation business. Central station power has the capability to achieve the low cost of electricity that the new marketplace will demand. And domestic coal reserves will provide the long-term low-cost fuel that can make this possible. However, the economics of scale of central station facilities is essential for coal plants to realize low-electricity production costs.

VI. TOMORROW'S COAL-FIRED POWER PLANTS

A consensus exists in the rural electric program that new central station power plants will generally be smaller than in the past. A few hundred megawatts will be more typical than a thousand megawatt or more. And modular plants offering short construction lead times and consistent performance over a range of sizes will dominate.

Although the generation part of the utility business will likely be unregulated and compete in the open market for electricity sales, from the environmental point of view, it will continue to be strictly regulated.

Hundreds of pages of regulations have been drafted to implement power plant SOx and NOx reductions required under the nation's 1990 Clean Air Act. Now, in 1996, the legislative and regulatory focus has shifted to reduce the output of CO2 and other "greenhouse gases," which some scientists believe are causing global warming.

Too, solid waste from power plants is increasingly the focus of proposed regulations under such legislation as the Endangered Species Act, the Clean Water Act, the Toxic Substances Control Act, the Resource Conservation and Recovery Act, and the Comprehensive Environmental Response Compensation and Liability Act - better known as Superfund.

The evolutionary development process leading to vast improvements in coal-fired central station power plants began in the 1960s with the development of fluidized-bed boilers. Atmospheric fluidized-bed (AFB) and pressurized fluidized-bed (PFB) boilers were seen as a potentially better way for utilities to burn virtually all ranks of coal directly while meeting the old 90 percent sulfur-removal requirements of the nation's first Clean Air Act. While direct combustion of coal via fluidized-bed boilers offers many advantages and will continue to be an important power plant option in many parts of the country, NRECA believes that coal gasification offers more advantages than direct combustion for the long-term highly competitive utility generation market.

Integrated Coal Gasification Combined Cycle (IGCC)

Coal gasification, in combination with new advanced power conversion technology such as high temperature turbines and fuel cells, clearly holds the key to central station coal-fired power plants that can compete in the bulk power generation market of the future.

In the early 1980s, ground was broken for the nation's first IGCC power plant at Southern California Edison's Coolwater site in Daggett, CA. This fundamental change in research direction away from direct coal combustion toward coal gasification was in recognition of the greater potential that coal gasification offered in terms of overall environmental performance and costs.

With direct coal combustion, impurities such as sulfur compounds and particulates must be cleaned from the post-combustion gas stream. The key advantage of IGCC is that gasification changes the fuel form from a solid to gasified coal which enables the impurities to be removed before combustion.

In the 100 mW Coolwater demonstration plant, a coal-water slurry was gasified in the presence of oxygen using a Texaco gasifier. The hot raw gas was cooled down, ash particles and other carry-over were scrubbed from the mixture, and then sulfur was chemically stripped from the gas.

The end product was a clean gaseous coal-derived fuel burned in a combustion turbine to produce electricity. Waste heat from the turbine exhaust was recovered to produce additional electrical power through a steam turbine.

And now, in the late 1990s, the U.S. Department of Energy, along with continuing electric utility industry R&D, has made significant progress toward demonstrating major improvements to the basic IGCC cycle

that could usher in coal gasification combined-cycle as the standard central station power plant for the next century.

An IGCC plant based upon the Coolwater configuration could be built today to operate on high-sulfur coal while emitting fewer pollutants than a comparable sized oil-fired power plant. But, the technology has improved from the Coolwater design at a significant rate due to advances being demonstrated under DOE's Clean Coal Technology program. The advanced IGCC system soon to enter demonstration testing at Sierra Pacific Power in Nevada will validate a number of these important advances. Technologies in Sierra Pacific's IGCC such as the pressurized fluidized-bed coal gasifier with in-bed desulfurization and full-stream hot gas cleanup, along with the use of a new generation of high-firing temperature combustion turbines, are critically important steps toward achieving the reduced electricity production costs that will be necessary to compete in the new competitive bulk power market.

Integrated Gasification Humid Air Turbine (IGHAT)

Further improvements to reduce the capital cost of IGCC plants will also be needed to ensure their success in this new competitive market. One approach to lower the cost of an IGCC power plant is to eliminate or perhaps simplify the equipment that is used to recover waste heat from the turbine exhaust and generate additional electricity. EPRI research on IGCC has been focused on how the waste heat could be recovered and expanded through the primary gas turbine power source instead of requiring a separate steam turbine to generate the additional electricity.

Under an EPRI research contract, engineers at Fluor Corporation identified a promising new concept for recovering the exhaust heat. Rather than having air pass directly from the compressor stage of a gas turbine into the combustion stage, this process diverts it into a cooler and then into a vessel known as a saturator. After the compressed air enters the bottom of the saturator, it flows upward against a stream of water that has been heated by the turbine exhaust, the compressed-air cooler, and any other sources of low-level heat. When the air leaves the top of the saturator, it has been humidified to between 10 percent and 40 percent water vapor. This humidified air is then further heated by the turbine exhaust and sent to the combustor, where fuel is added and burned.

In the process, the power produced by a gas turbine expander is proportional to the density of the combustion products that are being expanded. So, by substantially humidifying the air going into the

combustor, the density of the combustion stream is greatly increased. Thus, the power extracted by the turbine expander is proportionally increased, thereby producing much more electricity from the gas turbine generator. As a result, a power plant based on a coal gasifier and this turbine could have a heat rate as low as 8,500 Btu/kWh (over 40 percent efficiency) without using a steam bottoming cycle but still reclaiming low-level heat that would be difficult for other cycles to utilize.

In addition, use of the IGHAT cycle could help lower the capital cost of a gasification-based power plant by nearly 20 percent compared with the Coolwater IGCC approach. The reason is that in an IGCC plant, heat for raising steam is obtained by passing the coal gas through large coolers, which are the most expensive components of the gasification system. With the IGHAT cycle, the gas could simply be quenched with water.

A prototype of this turbine has not yet been constructed. But because of the relative simplicity of the IGHAT cycle, and the fact that it is based on current component technology, EPRI believes it could be fully commercialized by 2003.

Integrated Gasification Fuel Cell (IGFC)

An even more dramatic improvement to the coal gasification power plant involves eliminating the combustion turbine altogether and using a fuel cell to convert the coal gas directly to electricity through an electrochemical process. Such direct conversion potentially offers the highest efficiency and lowest emissions of any coal-based plant yet devised.

The integrated fuel-cell coal-gasification power plant, which could be commercially available by approximately 2010, might represent the final step in the nation's quest for clean coal technology. This system could potentially offer the following operational advantages:

- Virtually no SOx and NOx emissions, even with the very highest-sulfur U.S. coals;
- Modularity that lends itself to short construction lead times;
- A capital cost comparable to today's best technology, a new pulverized-coal-fired (PC) power plant with flue gas scrubbers;
- A 20 percent reduction in the bus-bar cost of electricity compared to today's PC plant with scrubbers; and
- A full 30 percent reduction in heat rate - which translates to a 30 percent reduction in CO2 discharge, should that become required as U.S. policy develops on global climate change.

Ideally the fuel cell selected for use with a coal gasification unit should operate at about the same temperature as the gasifier. The most promising candidate is a fuel cell using a molten carbonate electrolyte. The molten carbonate fuel cell (MCFC) technology has been operated successfully on gasified coal. Moreover, it is now operating in a 2 mW electric utility demonstration plant at Santa Clara Municipal Utility in Southern California, and it is being accelerated into commercialization by the electric utility industry's Fuel Cell Commercialization Group (FCCG).

An MCFC produces electricity directly from either gasified coal or natural gas fuel and air without a combustion process. An electrochemical reaction takes place between the hydrogen from the fuel and the oxygen from the air in a closed container, with the molten carbonate electrolyte maintained at 1200°F.

This reaction produces electricity in a manner resembling a battery. It makes no noise. The byproducts are pure water and carbon dioxide.

The first integrated gasification fuel cell cycle will likely be achieved by substituting a molten carbonate fuel cell for the gas turbine in the standard IGCC plant. This alone is predicted to offer a significant improvement in heat rate from 8,900 Btu/kWh down to 7,500 Btu/kWh, with a slight reduction in bus-bar electric costs.

But the big improvement is realized when the molten carbonate fuel cell is “chemically integrated” with the coal gasifier. With this approach, the heat rate of the IGFC plant could be further lowered down to 6,000 BTU/kWh, achieving a coal-pile-to-bus-bar efficiency approaching 60 percent, compared with about 37 percent for today’s best pulverized-coal technology.

Chemical integration, the key to such attractive performance, involves configuring the system in a manner such that the fuel cell’s unconverted fuel and the fuel’s heat content is recycled back into the gasifier. A special methane-producing gasifier would be required to maximize the chemical content of the coal-derived gas. Also, a hot gas clean-up step would be employed to clean the coal gas for use in the fuel cell without first cooling it down.

These are, of course, engineering developments that would have to take place successfully before such an advanced IGFC could be commercialized. But these are just engineering problems to be solved, and do not require any scientific breakthrough to achieve. As a result, EPRI believes this promising IGFC plant could become a commercial reality by 2010. If so, it could truly represent the final developmental step in the quest for clean coal-power generation.

VII. CONCLUSIONS

Deregulation of the electric utility industry would result in many changes to the way business is done today. In the unregulated, market-driven GENCO and ESCO businesses, electricity sales will be dominated by the low-cost providers.

ESCOs could successfully capture up to about 10 percent of the 175 gigawatts of new U.S. capacity needed by 2010 with dispersed generation. Dispersed generation electricity costs will be able to bear a premium above central station bulk power generation because the ESCO customers will be provided additional value-added services. Also, distributed generation will realize some payback from deferred transmission or distribution construction.

Central station power plants are expected to continue to provide the major portion of the nation’s new bulk power needs. But only very competitive low-cost generating stations will be constructed. These will

likely be built in smaller increments of 100 mW or so compared to today's larger plants.
Coal will continue to be a major factor in central station bulk power generation. And the economics and environmental performance of coal gasification combined cycle power plants will likely position this option as the dominate technology for coal fired central station generation.

DOE's clean coals technology program has been a major factor in bringing coal gasification combined cycle power plants to commercial readiness. Without this promising option, the nation's abundant coal resource might not continue to be in demand in competitive utility markets where low-cost dominates but emission regulations continue to tighten. But further progress on capital cost reduction and performance improvement is essential to ensure coal's long-term place in such a market.